AD-A127 384 BREAK UP OF VORTEX RINGS IN IMPINGING TURBULENT JET FLAMES(U) SHEFFIELD UNIV (ENGLAND) A J YULE 01 JUN 81 DA-ERO-79-G-0031 1/1

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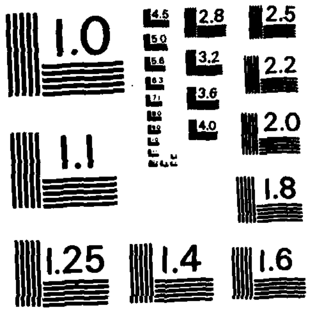
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report describes progress on the study of large eddies in flames which has benefited from support by ERO, U.S. Army. The work has clearly demonstrated the existence and importance of the coherent large eddy motions in (i) Gas flames impinging on a flat plate; (ii) Free gaseous diffusion flames; (iii) An axisymmetric fuel spray. The measurement programme has developed and (i) used: Simultaneous measurements of velocity, temperature and ionisation level, with the derivation of covariances and spectra; (ii) Space-time cross-correlations,

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using pairs of ionisation probes or thermocouples; (iii) Arrays of axially spaced thermocouples, to "follow" eddies downstream; (iv) A novel "top-hat" light-distribution LDA Particle Sizing System for simultaneous measurements of droplet sizes and velocities.

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BREAK UP OF VORTEX RINGS IN IMPINGING TURBULENT JET FLAMES

Second Annual Technical Report

by

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1 June 1981

EUROPEAN RESEARCH OFFICE

United States Army

London England

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Abstract

This report describes progress on the study of large eddies in flames which has benefitted from support by ERO, U.S. Army. The work has clearly demonstrated the existence and importance of the coherent large eddy motions in (i) Gas flames impinging on a flat plate. (ii) Free gaseous diffusion flames. (iii) An axisymmetric fuel spray.
The measurement programme has developed and (i) used: Simultaneous measurements of velocity, temperature and ionisation level, with the derivation of covariances and spectra. (ii) Space-time cross-correlations, using pairs of ionisation probes or thermocouples. (iii) Arrays of axially spaced thermocouples, to "follow" eddies downstream. (iv) A novel "top-hat" light-distribution LDA Particle Sizing System for simultaneous measurements of droplet sizes and velocities.

Experimental Programme

Impinging Jet Flame

Flow visualisation films have been taken of flames produced by a round propane jet impinging on a flat plate. The 'roller' eddies were observed on the plate for all conditions (except laminar flow).

A measurement programme has been conducted, using an LDA system to measure mean and r.m.s. velocities in the attached flame and in the fuel jet before impingement. Measurements were also made in non-burning versions of the same flows. Data were reported in earlier Quarterly Reports. For the cold flow cases there was general agreement with the parallel cold jet experiment at Lyons.

Free Jet Flame

It has been concluded that the eddies seen on the flat plate are basically similar to those found in free jet difussion flames. Measurements have been made in the flames of this type using laser anemometry (velocity U), miniature thermocouples (temperature T), ionisation probes (detection of reaction

zones: Fig. 1), Laser-schlieren (detection of density fluctuations: Fig. 2) and the simultaneous measurement of two or more variables (Fig. 3).

As an example, Fig. 4 shows simultaneous time histories of velocity and temperature. Fig. 5 shows the results of analysing data to obtain (i) autocorrelations, (ii) probability density functions, and (iii) joint P.D.F."S.

Data can also be presented in the form of frequency spector, for example Fig. 6 shows density fluctuations at different distances downstream. Simultaneously acquiring signals at a large number of longitudinally spaced positions permits one to track "events" as they move downstream. Fig. 7 shows thermocouple data demonstrating this technique.

Space Time Cross- Correlation peaks, for ionisation probe signals, gives information on the average shape of reaction zones and on their convection downstream. Fig. 8 shows data obtained in this manner.

All of these results are, or will be, prepared in forms suitable for publication.

Spray Experiments

Investigations of a fuel spray, vaporising in a coflowing secondary stream, have been conducted using cine-photography and newly developed laser tomography and LDA Particle Sizing techniques. The experiments show the existence of large coherent eddies, within which the smaller droplets concentrate, whilst larger droplets penetrate through the eddy boundaries into the secondary stream. The new LDA technique produces data on droplet diameter-velocity correlations, showing the lag between gas and droplet velocities, for the larger droplets.

Discussion

The results of this investigation have shown the existence and importance of large eddies in several classes of turbulent flow: cold jet flows, burning jet flows, impinging flames and liquid sprays. The detailed gas flame measurements have shown that these eddies tend to interface burning zones (or flamelets) wrapped around them. Near the burner nozzle, the eddies, and thus the flamelets, are orderly and vortex-ring like. They are particularly clearly visible in the case of a flame impinging on a plate. Further downstream the eddies become three-dimensional and contain smaller scales of turbulence. However the flamelets can still be identified. In particular individual flamelets can be followed from their formation, near the nozzle, into the turbulent zone and for many nozzle diameters downstream (often to the end of the visible flame).

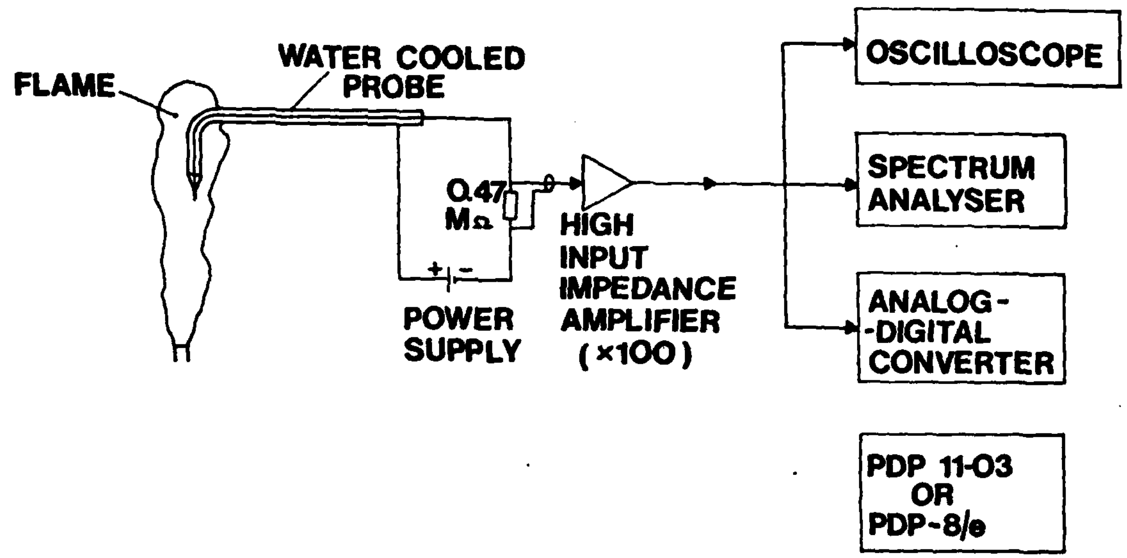
FLAME
WATER COOLED PROBE
0.47 MΩ
POWER SUPPLY
HIGH INPUT IMPEDANCE AMPLIFIER (×100)
OSCILLOSCOPE
SPECTRUM ANALYSER
ANALOG-DIGITAL CONVERTER
PDP 11-03 OR PDP-8/e

Figure 1

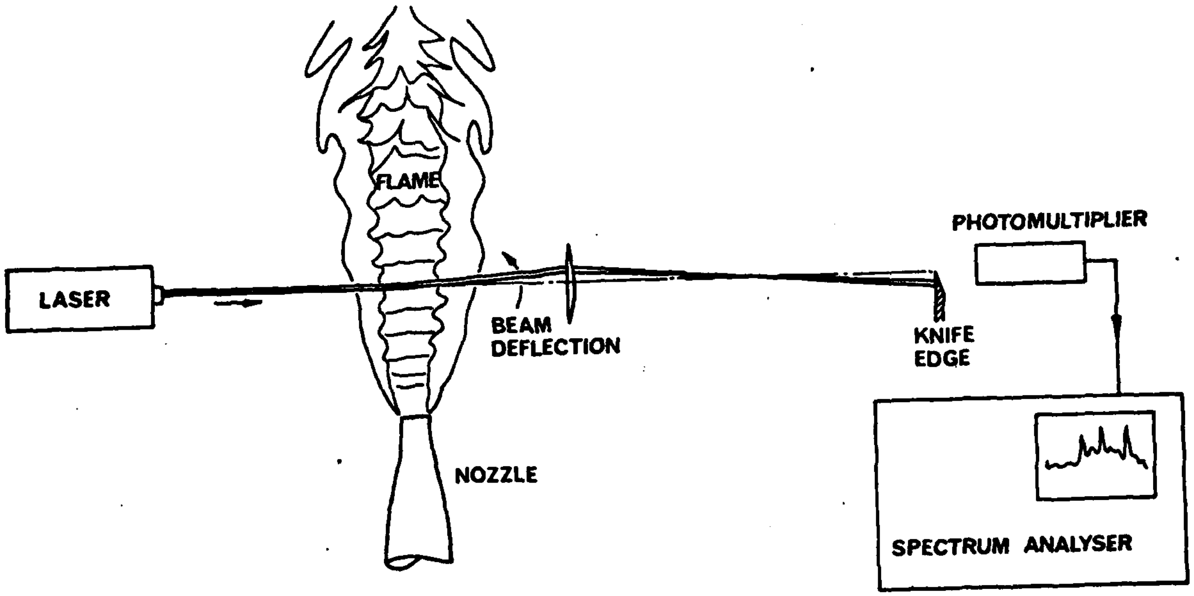
FLAME
LASER
BEAM
DEFLECTION
NOZZLE
PHOTOMULTIPLIER
KNIFE
EDGE
SPECTRUM ANALYSER

Figure 2

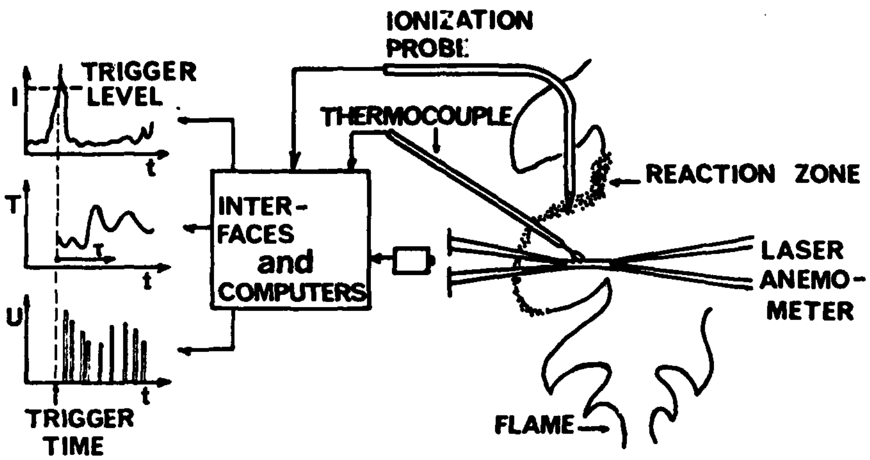

Fig. 3 Conditional Sampling to Measure Local Average Eddy and Reaction Zone Structure

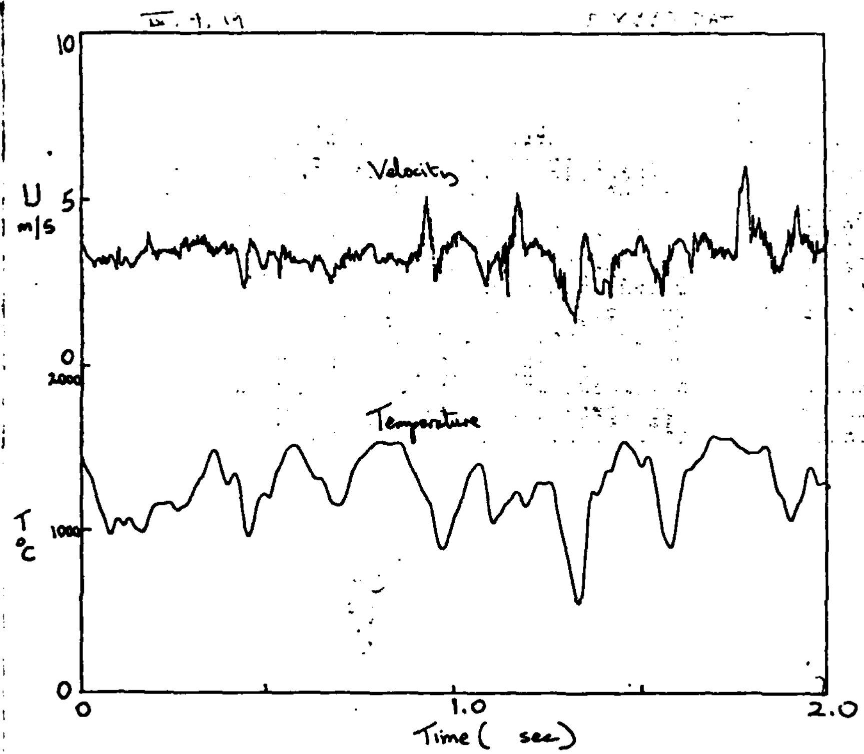

Figure 4

Velocity & Temperature Time Histories

$Re = 10^4$, $\phi = 3.69$

$x = 4D$, $r = 19$mm

4

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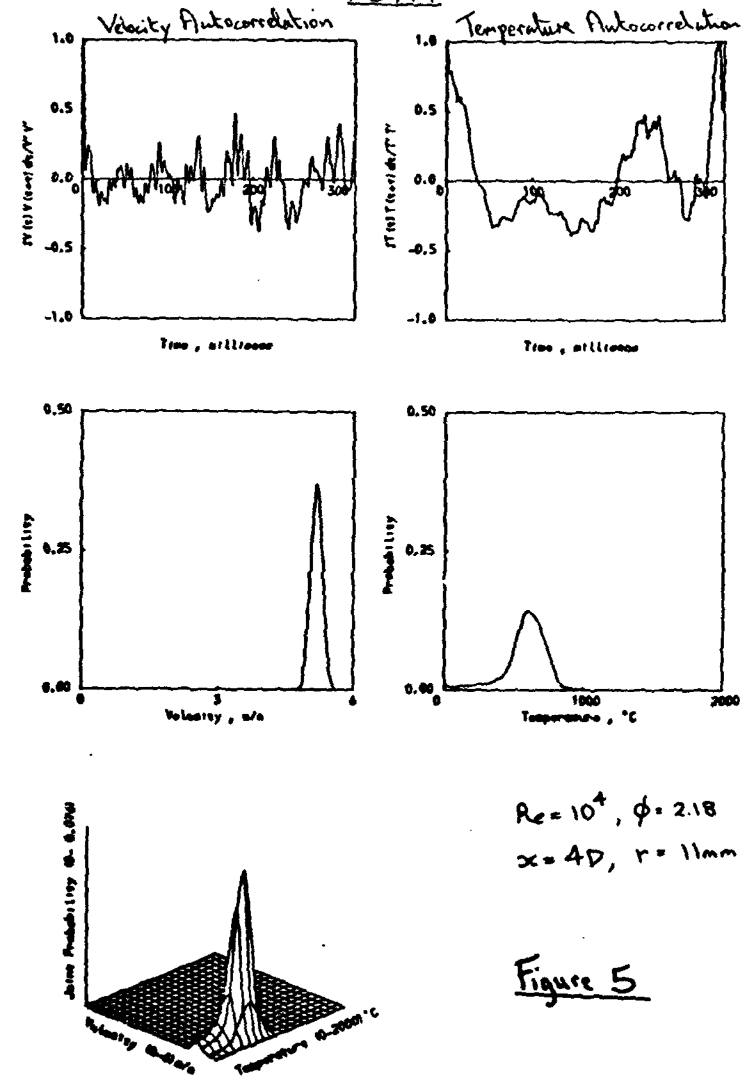

Re = 10^4, ϕ = 2.18
x = 4D, r = 11mm

Figure 5

5

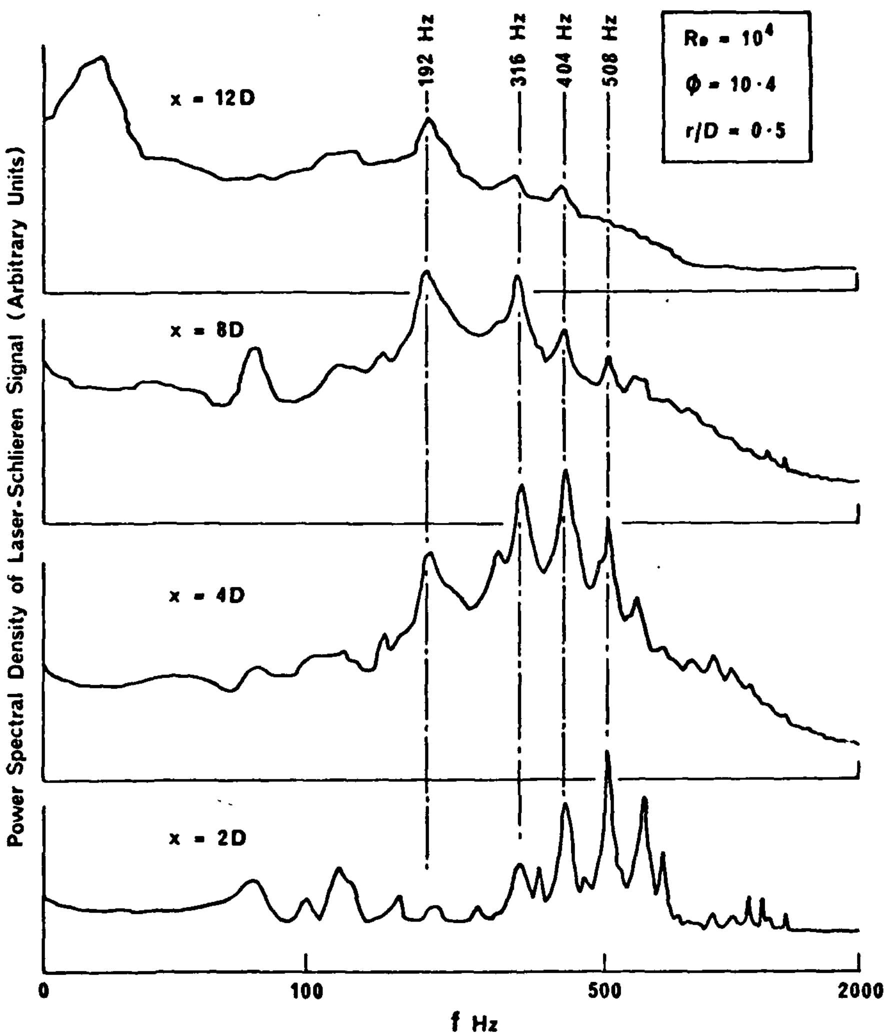
192 Hz
316 Hz
404 Hz
508 Hz
Re = 10^4
ϕ = 10·4
r/D = 0·5
x = 12D
x = 8D
x = 4D
x = 2D
Power Spectral Density of Laser-Schlieren Signal (Arbitrary Units)
0
100
500
2000
f Hz

Figure 6

FIGURE

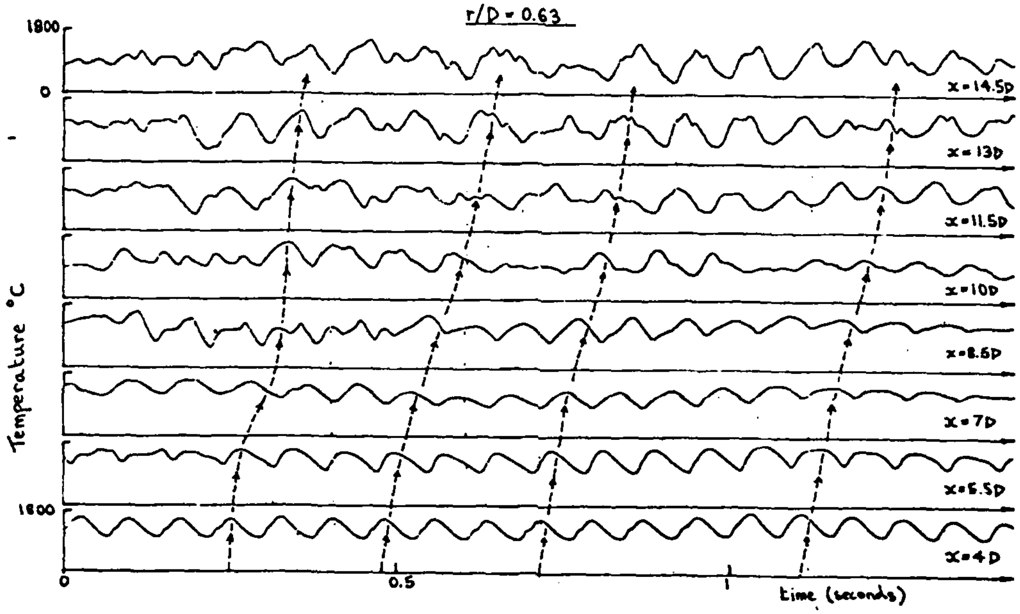

Figure 7

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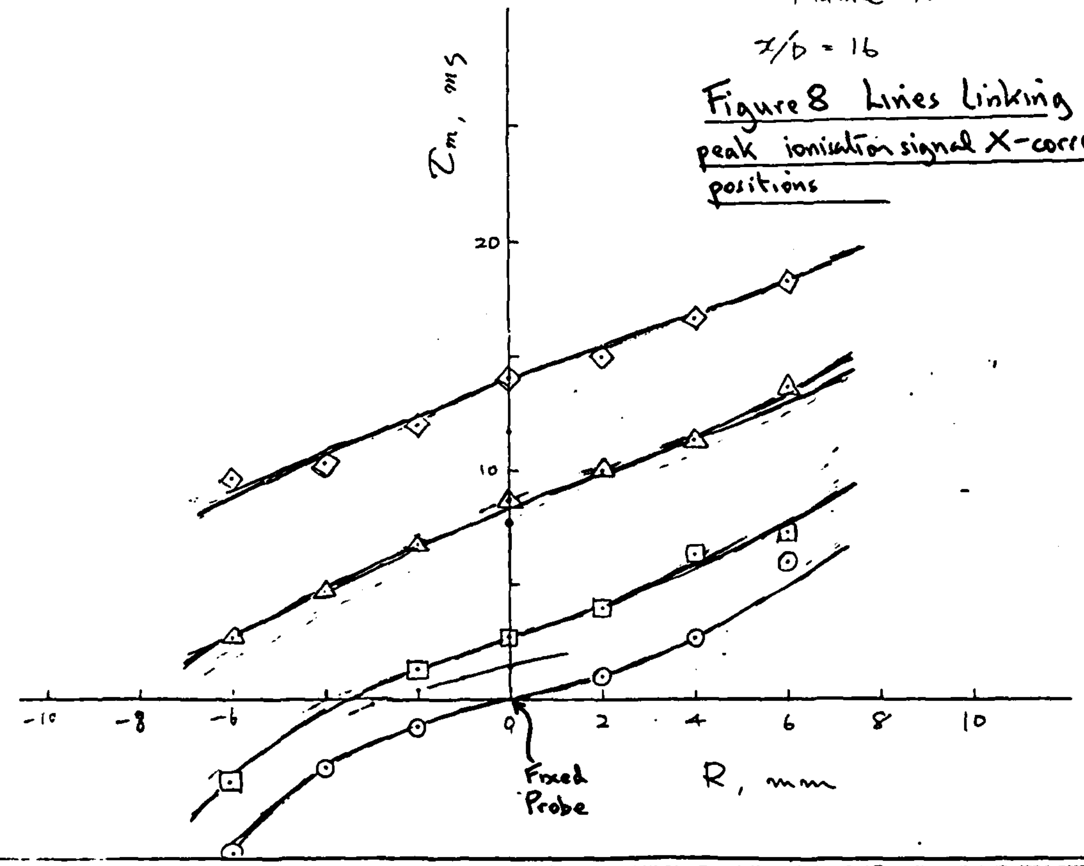

Figure 8 Lines linking peak ionisation signal X-correlation positions

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